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APPLE AND PEAR BLACK-SPOT.

THEIR APPEARANCE, CAUSE, AND CONTROL.

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(1.) APPLE BLACK-SPOT, *VENTURIA INAEQUALIS* (CKE.) ADERH.*

EXCEPT in favoured localities where the humidity is low during the growing season, such as in Central Otago and certain localities in Marlborough and North Auckland, black-spot is common on apples throughout New Zealand. It occurs also in Australia, South Africa, North America, and Europe.

In New Zealand the conidial or summer stage appears in the form of dark-coloured spots on the leaves, fruits, and shoots. The ascigerous or winter stage occurs as a saprophyte, the perithecia developing in the spring from mycelium which has wintered over in dead leaves. This stage does not occur on fruits or shoots, being found only in the tissues of the dead leaves.

Apple black-spot is not confined to the cultivated apple (*Pyrus malus* L.), since in Europe and North America it has been recorded on related species of the genus *Pyrus*. For example, in North America it occurs on the wild crab (*Pyrus coronaria* L.). It is unable to infect hawthorn or pear, the black-spot of these hosts being caused by related species.

ECONOMIC IMPORTANCE.

Black-spot is the most serious apple-disease with which the orchardist has to contend, as it not only weakens the tree by damaging the leaves, but reduces the market value of the fruit through the development of disfiguring spots, scabs, and cracks on the epidermis. In cases of severe infection the crop may become a total loss, owing to the developing fruits being so damaged as to fall to the ground at the time of setting or shortly after. The defoliation following upon severe leaf-infection impairs the following season's crop, as the development of fruit-buds is largely dependent on the leaves of the previous season. As a result of fruit-infection loss may be caused in four ways: (1) The fruits may fail to set owing to their being killed outright by the fungus; (2) as a result of infection young fruits may fall to the ground; (3) young fruits may become distorted, badly scabbed, or cracked, and thus be rendered unsaleable; (4) the quality of the fruit and its keeping properties may become impaired by the development of disfiguring marks on the surface.

* Synonyms: *Sphaerella inaequalis* Cke.; *Venturia Pomi* (Fr.) Wint.; *Venturia inaequalis* (Cke.) Wint.; *Fusicladium dendriticum* (Wallr.) Fcl.; apple-scab.

In the last case the disease does not result in the rotting or breaking-down of the tissues of the apple, as is the case with bitter-rot and other similar fruit-rotting fungi. On the contrary, the most noticeable effect may be a mere superficial disfigurement of otherwise mature and healthy fruit; nevertheless this defect in quality is often enough in itself to render a large portion of a crop unsaleable. Serious as this may be, it is by no means the worst feature of black-spot; in several ways it may directly reduce the quantity of fruit. This aspect of the

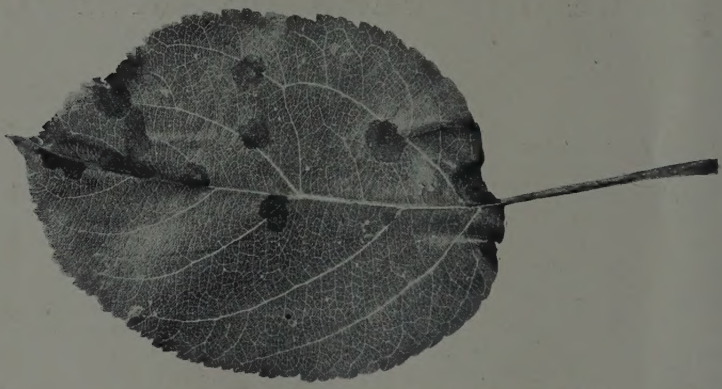

FIG. 1. LEAF-INFECTION: DOUGHERTY APPLE LEAF WITH LESIONS ON UPPER SURFACE. NATURAL SIZE.

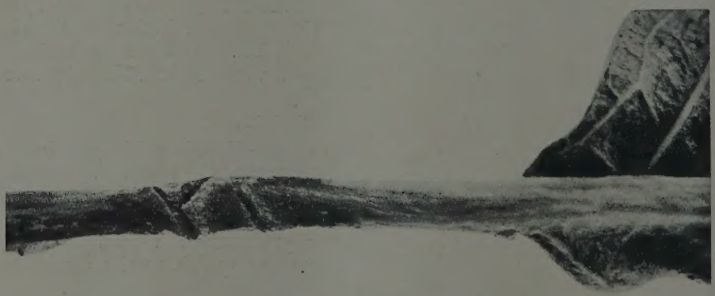

FIG. 2. PETIOLE-INFECTION, SHOWING SMALL CANKERS WHICH ARE FORMED AND CAUSE PREMATURE LEAF-FALL. × 6.

[*Photos by E. Bruce Levy.*

disease is more liable to pass unnoticed, but it is immeasurably more disastrous in its results. Black-spot thus affects the quantity as well as the quality of the output—the two factors on which the profit of the orchardist depends.

APPEARANCE AND EFFECT ON THE HOST.

Black-spot makes its appearance on the leaves about the first week in November, the exact time varying with the blossoming-period of the

host variety (Fig. 1). It is not generally observed in this early stage, owing to the spots being small, scattered, and situated chiefly on the under-surface of the leaf. Their occurrence in this position is due to the fact of the under-surface being first exposed as the leaf emerges from the bud. The spots are olivaceous in colour, and have at first a somewhat indefinite outline, owing to the hyphæ of the fungus radiating outwards from the source of infection. Though few at first, they may later increase in numbers, until the whole leaf-surface becomes covered with small spots, which grow until their margins meet, so that ultimately nearly the whole surface may be involved. Sometimes the portion of the leaf-tissue below these spots becomes upraised and presents a bullate or blistered appearance, the other surface becoming correspondingly depressed or concave. The spots on the lower surface are usually more irregular in outline than those of the upper surface, and tend to follow the direction of the main veins. The leaf-tissues under the centre of the old spots are often killed outright, when they assume a brown colour and occasionally fall away, leaving perforations in the leaf. Infected leaves frequently become incurved or distorted, generally remain smaller in size, and usually fall prematurely, so that in a season when black-spot is prevalent the trees may become completely defoliated. On the petioles small cankered areas are formed which cause the death of infected tissues, followed by premature leaf-fall (Fig. 2).

Black-spot first appears on fruits shortly after they have set, when it shows on the calyx and pedicels, and has been recorded on petals, anthers, and pistils. When pedicels are infected the young fruits as a rule fall off, their further development and nutrition being prevented by the hyphæ of the fungus. When spots appear on the calyx, distortion of the fruit usually follows, the parasitized cells being damaged to such an extent that they are unable to develop further, and as growth continues in the cells in their vicinity misshapen fruits result. Such distorted fruits commonly fall, as owing to unequal growth they come into contact with other developing fruits and are forced from the spur to which they are attached. On maturing fruits the spots appear as olivaceous, more or less circular areas, surrounded by greyish edges formed from the marginal portion of the undissolved part of the cuticle, which has been forced apart from the epidermal cells by the invading hyphæ (Fig. 3). Fruit-infection usually occurs at the calyx end, as this is the area most exposed to moisture and the wind-borne spores. After infection the spots continue to enlarge in a circular manner; then after a time their centres usually become exposed, as the spores are carried away by wind or rain, when they appear as brownish russeted areas (Fig. 4). On actively developing

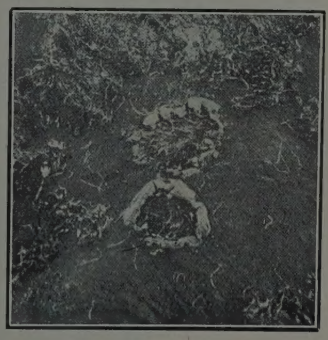

FIG. 3. FRUIT-INFECTION: LESIONS SURROUNDED BY UPRAISED CUTICLE. × 10.
[*Photo by E. Bruce Levy.*

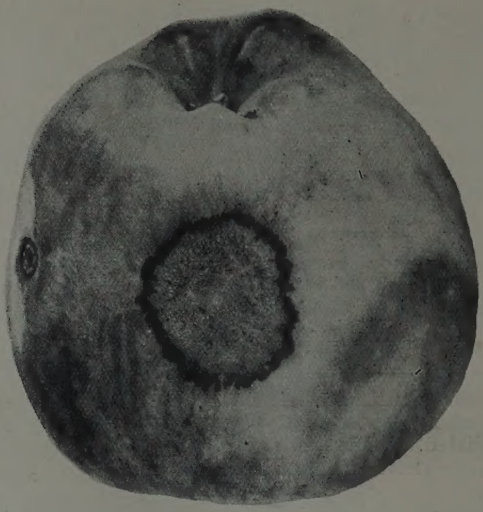

FIG. 4. EARLY INFECTION ON DELICIOUS APPLE. NOTE LARGE SIZE OF SPOT AND RUSSETED AREA IN CENTRE. NATURAL SIZE.

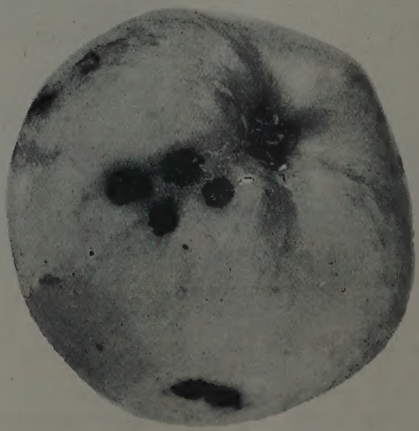

FIG. 5. LATE INFECTION ON DOUGHERTY APPLE. NOTE SMALL SIZE OF LESIONS. NATURAL SIZE.

[*Photos by E. Bruce Levy.*

fruits the spots become depressed or sunken (Fig. 4). This is due to the fact that immediately beneath the spots corky tissue is formed, which is hard and unyielding, growth of the host-tissues being thus prevented in this region, while the surrounding healthy tissues continue their development beyond it. These spots may coalesce, and after the spores have disappeared the internal pressure of the developing host cells often causes the formation of large cracks, which afford opportunity for the entry of the spores of fruit-rotting fungi.

When late infection occurs on mature or nearly mature fruits the spots are as a rule minute, and the fruits do not show any depressed areas or russet-marks (Fig. 5). Black-spot development may continue in cool store, spots in this case presenting large greyish borders surrounding intensely black centres (Fig. 3). The intense coloration is due to the masses of dark-coloured spores, which in the still atmosphere of a cool store are not carried away, but remain where they are formed.

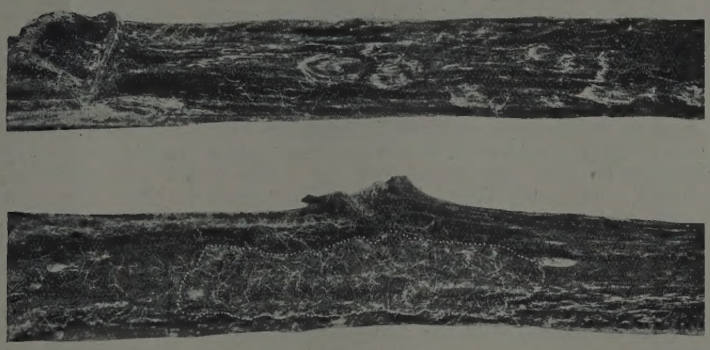

FIG. 6 (UPPER). APPLE-SHOOT INFECTION: PUSTULES ON DOUGHERTY LATERAL. × 4.

FIG. 7 (LOWER). APPLE-SHOOT INFECTION: LESIONS ON WOOD SIMILAR TO THOSE FORMED ON FRUITS. DOTTED OUTLINE SHOWS SIZE OF LESION. × 4.

[*Photos by E. Bruce Levy.*

Shoot-infection varies somewhat in appearance according to the host variety attacked. On certain varieties the epidermis of young shoots may be studded with light-brown spots consisting of blister-like pustules containing conidia in their centres (Fig. 6). In other varieties infected shoots are somewhat swollen and blistered, the bark ultimately peeling off in flakes; or lesions resembling those on fruits may be formed (Fig. 7). Vigorously growing shoots and water-shoots appear to be more readily attacked. These lesions tend greatly to weaken the shoots and render them liable to fracture; moreover, they facilitate the attacks of diplodia-canker, black-rot, and other canker-forming fungi.

Inset—Black-spot.

LIFE-HISTORY OF THE CAUSAL ORGANISM.

Apple black-spot is caused by the ascomycetous fungus *Venturia inaequalis* (Cke.) Aderh. The conidial stage of the latter, long known as *Fusicladium dendriticum* (Wallr.) Fcl., is the active agent, the ascigerous stage being merely saprophytic, occurring on dead leaves. Nevertheless it is mainly this saprophytic stage that spreads the disease afresh each season.

In early November black spots begin to appear on leaves and developing fruits, arising as a result of infection either from ascospores produced from perithecia formed in dead leaves, or from conidia produced from stromata which have overwintered on shoots.

If a spore (ascospore or conidium) alights on a leaf or fruit surface, and conditions prove favourable, it germinates and produces a germ-tube which penetrates the cuticle, beneath which it branches repeatedly to form a mycelium, which derives its nourishment from the solution of the cuticle and from cells of the epidermis or parenchyma lying immediately beneath. About a fortnight after infection this mycelium develops a stroma consisting of closely woven masses of hyphæ (Fig. 8, *st*); from it upright hyphæ (conidiophores) are produced, arranged in closely packed columnar masses (Fig. 8, *con*); on their apices the olive-coloured elliptical conidia are produced (Fig. 8, *sp*), being cut off in succession from the conidiophores. During the development of the stromata and conidiophores the cuticle is gradually forced away from the epidermis, and at this stage appears as a greyish border surrounding the spore masses (Fig. 3). The conidia are readily detached, and, being light, are carried by wind or other agency to neighbouring leaves or fruits, which in turn may become infected. Conidia remain viable for but a short time, so that subsequent infection must occur from conidia produced throughout the season from stromata on leaves, fruits, or shoots.

Infected leaves sooner or later fall to the ground, where they become permeated with the dark-coloured mycelium. In the autumn perithecia begin to form from this mycelium, but do not reach maturity until after the winter months, their development being completed in August and September. A perithecium is a flask-shaped receptacle the walls of which are formed of closely woven hyphæ (Fig. 9). In its early stages it is filled with hyphal filaments, certain of which later develop into asci (Fig. 9, *a*), each containing eight two-celled ascospores. The ascospores at first are colourless and unicellular, but at maturity they become unequally septate and yellowish-green in colour (Fig. 10, *as*). During development the perithecium is completely buried within the leaf, but as it reaches maturity it approaches the leaf-surface until the neck, which is perforated with a minute opening (the ostiolum, Fig. 9, *os*), pierces the epidermis and opens on to the free surface (usually the lower) of the leaf. As the perithecium matures, the neck, which is at first smooth, becomes crowned with a few coarse black bristles (Fig. 9, *br*). Perithecia, as a rule, develop only on leaves that have been somewhat protected during the winter months; leaves found under hedges, clods, &c., contain numerous perithecia, whilst those lying exposed on wet ground have few or none. From the middle of September until the first week in December, on the occurrence of rainy weather, the ascospores are discharged from the perithecia into the air, being ejected sufficiently high to be caught in

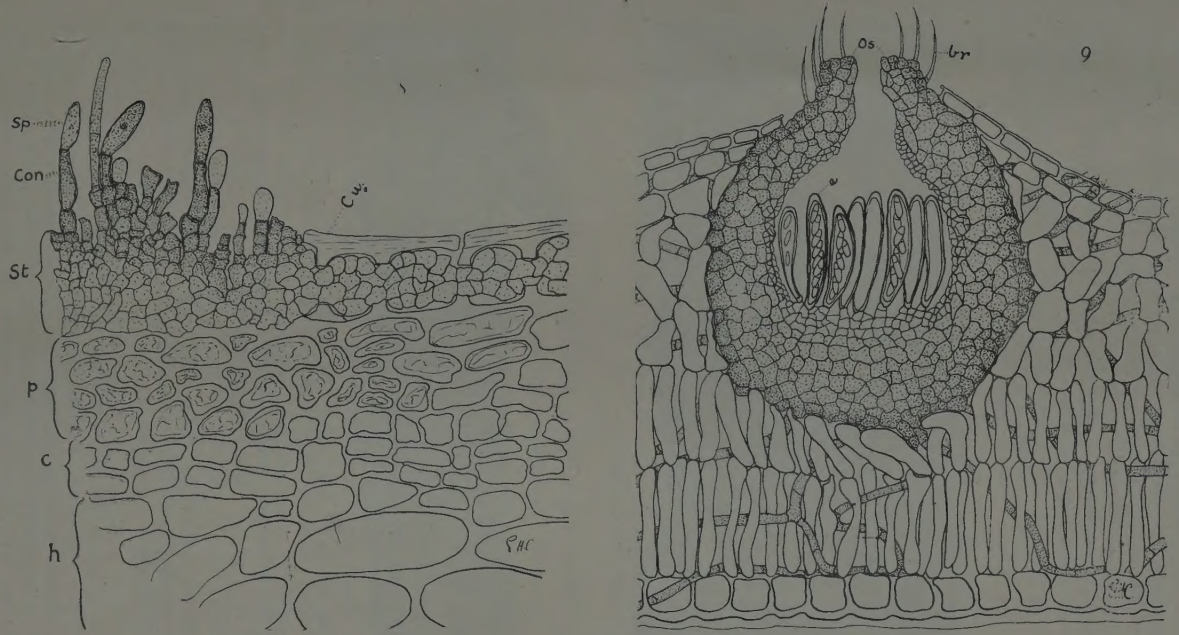

Fig. 8. Fruit-infection : Section through lesion on fruit—(*c*) cambium ; (*con*) conidiophores ; (*cu*) cuticle ; (*h*) healthy parenchyma ; (*p*) plasmolized cells affected by the fungus, brown in colour ; (*sp*) conidia ; (*st*) stroma formed of closely woven hyphæ. × 375. Camera lucida drawing.

Fig. 9. Section through leaf containing perithecium opening on to lower surface—(*a*) asci ; (*br*) bristles ; (*os*) ostiolum. × 340. Camera lucida drawing. [*Original.*

and carried by air-currents to developing leaves and fruits in the neighbourhood. The discharge of ascospores is dependent on the presence of abundant moisture, which causes certain portions of the asci and perithecia to swell to such an extent that the enclosed asci are subjected to considerable pressure, this forcing out their contained ascospores through the perithecia into the air. So great is the pressure developed by the swelling of these hygroscopic portions that the entire perithecium is sometimes shattered, asci and spores being ejected into the air with considerable force, the embedded base of the perithecium alone remaining in the leaf-tissues. Not only is abundant moisture essential for the discharge of the ascospores, but it must also be present on the leaves before an ascospore can germinate or its germ-tube pierce the cuticle.

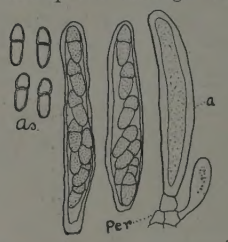

FIG. 10. ASCI AND ASCOSPORES.
(*a*) Asci; (*as*) ascospores; (*per*) portion of perithecium to which asci are attached. × 400. [*Original.*

When an ascospore germinates it produces a germ-tube (usually two are produced, one from each cell), which penetrates the cuticle, beneath which it branches repeatedly, giving rise to a stroma on which conidia are produced. The production of conidia thus completes the cycle.

The fungus may winter over on infected shoots, when in spring it produces conidia capable of causing leaf, fruit, and shoot infection as soon as leaves appear.

(2.) PEAR BLACK-SPOT, *VENTURIA PIRINA* ADERH.

Synonyms: *Fusicladium Pirinum* (Lib.) Fcl.; pear-scab.

This disease is very similar in appearance to apple black-spot, and by orchardists is usually regarded as identical. The causal organism differs in several details of structure of the fructifications, as well as in its inability to infect any host other than the pear. It causes a leaf and fruit spot similar in appearance to apple black-spot, while its life-history, economic importance, and control are similar. It differs from apple black-spot in that it commonly produces conidia on young shoots and laterals (Figs. 11, 12), a condition known for the past fifteen years to exist in New Zealand. The writer has shown elsewhere that conidia have been produced continuously on shoots over a period of nine months, and that viable conidia occurred on shoots during the whole of that period. There is therefore little doubt that with this species shoot-infection is one of the means of carrying the organism over the winter months. The fact must not be lost sight of, however, that perithecia are produced abundantly on fallen leaves, and that ascospores so produced infect the leaves and fruits of this host in the spring.

GENERAL CONSIDERATIONS.

From the foregoing it becomes apparent that black-spot is carried over the winter by mycelium embedded in the dead leaves and by mycelium overwintering in infected shoots. We have seen that from this mycelium in the dead leaves perithecia containing ascospores are

developed in the spring. We know that these ascospores, which are discharged some time prior to, during, and for a short time after blossoming, are one of the sources of primary infection, and that when they infect leaves or fruits they give rise to mycelium from which conidia are produced, these conidia in turn causing infection throughout the season. Furthermore, we have seen that from mycelium embedded in infected shoots are produced conidia which are capable of producing the disease as soon as the leaves and fruits appear.

FIG. 11 (UPPER). PEAR-SHOOT INFECTION. USUAL FORM. NOTE BLISTERED AREAS. × 6.

FIG. 12 (LOWER). PEAR-SHOOT INFECTION. UNUSUAL CONDITION SHOWING DEPRESSED AREAS. × 6.

[*Photos by E. Bruce Levy.*

Thus it would appear that in order to enable the control of the disease to be carried out we must either (*a*) prevent primary infection by the destruction of leaves containing perithecia, and deal with shoot-infection in such a manner that formation of conidia is prevented, or (*b*) prevent ascospore and conidial infection by covering developing foliage and fruits with a protective spray.

(*a.*) If the fungus were perpetuated by ascospores alone, then the destruction of all leaves containing perithecia would prevent primary infection, clean fruit would result, and spraying would be unnecessary.

Unfortunately, this would be impossible in orchard practice, as leaves containing large numbers of perithecia commonly occur in such places as under hedges, &c., where they cannot be buried by the plough. Destruction of fallen leaves by hand would be impracticable, owing to the time that this would take and the labour that would be required. Doubtless, infection is minimized by the destruction of a large proportion of the leaves, so that where possible cultural operations should be carried out before ascospore-discharge begins in the spring—that is, before September.

Even if the destruction of fallen leaves were practised, infection would still be liable to occur from the conidia developed on infected shoots. The cutting-out of these would not be entirely satisfactory, as this treatment would require a modification of the present lateral system of pruning, and would, moreover, necessitate the examination of every shoot, an operation which would be impracticable in a commercial orchard during pruning operations.

(*b*.) If ascospore-discharge occurred during a short period only, then a single spray application at this time would be all that was necessary to combat this phase of black-spot infection. Unfortunately, spore-discharge occurs over a period of weeks, beginning some time before blossoming and continuing for some time after. Infection does not cease with the completion of ascospore-discharge, but continues throughout the whole of the growing-period and afterwards, occurring even in cool store. Throughout the season conidia are being produced on leaves and fruits, and it is these that cause late infection, as they may be carried by air-currents for long distances. Thus even an orchard that has been sprayed thoroughly during the blossoming-period is subject to infection from these wind-borne conidia. Spray applications, therefore, are necessary throughout the season to prevent infection. When fruit is to be placed in a cool store a spray application before picking will be of value in preventing infection while in the store.

To summarize: A series of spray applications is necessary, so that the danger period of ascospore infection may be effectively covered, conidia on shoots destroyed, and subsequent development of conidia on leaves and fruits prevented.

CONTROL.

(In collaboration with the Director of the Horticulture Division.)

It has been shown in the foregoing matter that control of black-spot by destruction of infected leaves is impracticable, not only because of the difficulty of destroying all the leaves, but because the danger of infection from diseased shoots still remains. Nevertheless, as destruction of infected leaves would tend to minimize infection by reducing the number of ascospores, it should be practised wherever feasible. It would therefore be advisable to plough deeply in the autumn and dig under all portions left by the plough, thus burying as many leaves as possible. Orchardists are recommended to spray according to the following schedule, which has been found to control this disease effectively in the orchard districts of Auckland, Hastings, and Nelson.

Spray Schedule for the Control of Apple and Pear Black-spot.

No.	Time of Application.	Spray.
1	Green-tip	5–4–50 bordeaux, or 1–10 lime-sulphur.
2	Between open-cluster and pink stage	3–4–50 bordeaux, or 1–30 lime-sulphur.
3*	Calyx-spray (petal-fall; or when majority of petals have fallen)	1–100 to 1–120 lime-sulphur.†
4	Ten days later	1–100 to 1–120 lime-sulphur.
5	Every month until the fruit reaches maturity	1–100 to 1–120 lime-sulphur.
6‡	Immediately before picking ..	1–100 lime-sulphur.

* With this and subsequent sprays arsenate of lead, 3 lb. paste or 1½ lb. powder to 100 gallons, may be added for the control of codlin-moth and leaf-roller caterpillar.

† With some varieties 1–100 lime-sulphur is liable to scorch; in such cases the weaker mixture should be used.

‡ This application is required only when the fruit is to be placed in cool store for some considerable time, its object being the prevention of cool-store infection. It could be applied with advantage where the fruit was required for export.

This is but an empirical schedule, and will require to be modified somewhat according to the locality and variety. When in doubt the orchardist would do well to consult the Orchard Instructor for his district. It may be as well to stress the fact that it is the period and thoroughness of application, rather than the exact strength of the spray used, that is the governing factor in the control of black-spot.

The first four applications cover the period of ascospore infection; subsequent sprays are for the prevention of conidial (summer stage) infection. Lime-sulphur may be used throughout, particularly where a combined insecticide-fungicide is required; but better results will be obtained if the first two applications are of bordeaux mixture at the strengths given, this applying more particularly when the varieties are susceptible to black-spot or where trees have been badly infected the previous season.

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